A Home-made Ultrasonic Power Line Arc Detector

The device described in this article can help you track down power line noise sources to help utility crews more quickly resolve problems.

James T. Hanson, W1TRC

Even though BPL interference has captured the headlines for some time now, amateurs continue to be bothered by old-fashioned power line noise. In some areas, power line noise problems are actually getting worse due to utility company maintenance budget limitations.

A call to your local power company *should* be all that it takes to resolve power line noise problems. Radiation from leaky power equipment is a *nonintended emitter* in FCC speak and the power companies are required to address the issue. Unfortunately, in real life, an amateur is much more likely to achieve prompt resolution if he can point the power company towards the source of the noise. The relatively simple receiver described here can help you do exactly that.

Helping the Power Company will Help You

Due to the various potential sources of radio noise, it is advisable to do some investigation before contacting the utility company. For one thing, it is possible that the noise being picked up may not be power line noise at all, and it is also possible that the noise is coming from something in the amateur's own house or a close neighbor's house. Examples of possible noise sources include light dimmers, switching power supplies, electric fences, and even doorbells. Some utility companies have limited capability to pinpoint the source of noise, so anything the ham can do to locate the problem will only help to resolve the problem. It also happens that many noise sources are moisture dependent, so if you have a problem on rainy days and the investigative crews come out on clear days (that's when I'd want to climb a pole!), it can be a long time before the crew tracks down the problem.

There have been many excellent magazine articles and books published on how to determine the location of radio noise and one of the best sources of information is the ARRL Web site technical information service page titled "Track and Solve Electrical Interference."[1] The references on this site describe how to recognize and locate power line noise, and describe the best radio receiver devices and techniques to do this. In general, the articles point out that VHF or UHF AM receivers are the best for locating noise, because, at the higher frequencies, power line noise is generally weaker, so one must be fairly close to the source to pick it up. It is also possible to build or purchase some type of directional antenna for use at these frequencies. The antenna can be as simple as a dipole, with the nulls off the ends used as an indication of the direction of the interference.

Getting Closer is Even Better

Once the source of the radio noise has been narrowed to a particular utility pole or one of several poles, it is advantageous to verify the source of radio noise. One instrument that is capable of doing this is an ultrasonic detector. Arcing from a utility pole makes acoustic noise, as well as radiating RF. The sound is usually at ultrasonic frequencies around 40 kHz, and this requires special equipment to detect.[2] Commercial ultrasonic detectors have been available for a number of years but they have been very expensive. This article describes a homemade ultrasonic detector that can be built by the typical ham at reasonable cost.

[1]Notes appear on page 45.

Why Build an Ultrasonic Detector?

I have had and continue to have multiple sources of power line noise, all of which are intermittent. The strength of the noise varied from S7 to S9 +20 dB. Before contacting the utility company, I used a VHF MFJ-852 line noise meter to locate the general area of the noise sources and traced the noise to three different locations, all of which were within ¼ mile of my home. This was all done before I built an ultrasonic detector.

At this point, I sent a certified letter to the utility company, describing the noise problems I was having, and the steps I had taken to identify where I thought the problems were located. Within a few weeks, I received a telephone call from the utility radio lab informing me that they were sending out a person to investigate the noise problem. The person was coming out on a specific date to do the investigation. This bothered me a little bit since the noise was intermittent, and I wondered if the noise would cooperate with the scheduled investigation.

As it turned out, the noise did not cooperate, and on the day that the person came from the radio lab, all was quiet. The single tool that the investigator had to locate the noise was a commercial ultrasonic detector, but I could tell from my MFJ-852 line noise meter that everything was silent on this particular day. Fortunately, the person from the radio lab was sympathetic and scheduled another day to look for noise. On this second visit, two of the locations were generating noise

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at full blast, and the investigator found two sources of arcing at both locations. A work crew was scheduled to do the repairs.

Unfortunately, the work that was initially done by the repair crew did not solve the noise problem. Prior to the work, I had decided to build an ultrasonic detector for myself. This was an instrument that the utility company used and understood, and I could do my own independent investigation of exactly where the noise was coming from when the noise was present. After I continued to experience noise problems following the completion of the initial repair work, I was able to go to the locations on days that I was experiencing noise and was able to not only locate the pole but also the location on the pole that had the source of the arcing. After reporting this to the utility radio lab, they made additional trips to the site and were able to verify my measurements so additional repair work was done. The occurrence of noise has been substantially reduced, and the utility company has promised to clear up any remaining problems.

One of the features of an ultrasonic detector that makes it so valuable is its narrow beam-width. The 18 inch parabolic dish that I used has a directional beam width of about 1.5°. Because of this narrow beam width, it is possible to determine not only which pole has arcing, but also where on the pole the arcing is coming from. It is also surprising how loud the arcing can be. I have had the experience of being able to easily detect arcing from a pole while standing across the street from the pole that had an arcing insulator.

The Ultrasonic Detector Details

One of the first things I did when I decided to build an ultrasonic detector was an Internet search for construction details. I found that there is a large group of hobbyists who have built electronic detectors that could detect the ultrasonic sound of bats (the flying kind). The detectors fall into several general categories. One type of detector simply amplifies the high frequency bat signal and feeds the amplified output into a threshold comparator followed by a frequency divider to generate a lower frequency signal within the frequency range of the human ear. A second type of detector is classified as a frequency translator. These detectors operate like a direct conversion receiver and simply amplify and then mix the ultrasonic signal with a local oscillator to heterodyne the ultrasonic signal to audio frequencies, which can be heard with earphones. Because it preserves the amplitude and sound characteristics of the ultrasonic signal, this is the type of detector that I decided to build. A simplified block diagram of the detector is included in Figure 1.

The heart of the detector is a parabolic dish and a transducer capable of picking up ultrasonic sound. Several companies make low cost transducers that have a peak response at 40 kHz. This is fortunate, since this is also the frequency at which power line arcs are readily detected. The transducer I used was the Kobitone 255-400ER18, a stock item at Mouser Electronics. The output of the ultrasonic transducer is amplified in a low noise preamplifier and is then fed to a mixer in which the signal is heterodyned to audio frequencies by mixing with an oscillator that is offset from the 40 kHz ultrasonic signal. The resultant audio signal is filtered in a simple low pass filter and amplified to produce an audio output to a pair of earphones. The electronics operate from a single 9 V battery.

The parabolic dish assembly is a modification of a design that was built by Greg Kunkel.[3] In his original application, Greg used an audio microphone and a recorder to pick up and record bird songs. The beauty of Greg's design is that it uses an off-the-shelf Edmund Scientific parabolic dish and low cost, readily available PVC pipe fittings for the assembly. The modifications that I made to adapt the design for an ultrasonic detector included:

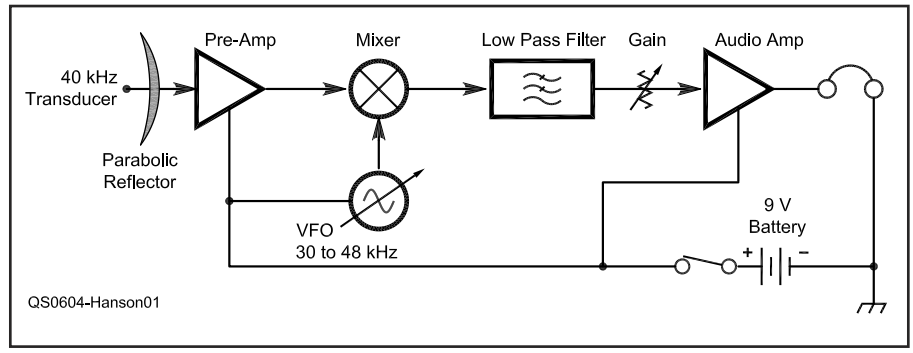

Figure 1 — Simplified block diagram of the ultrasonic detector.

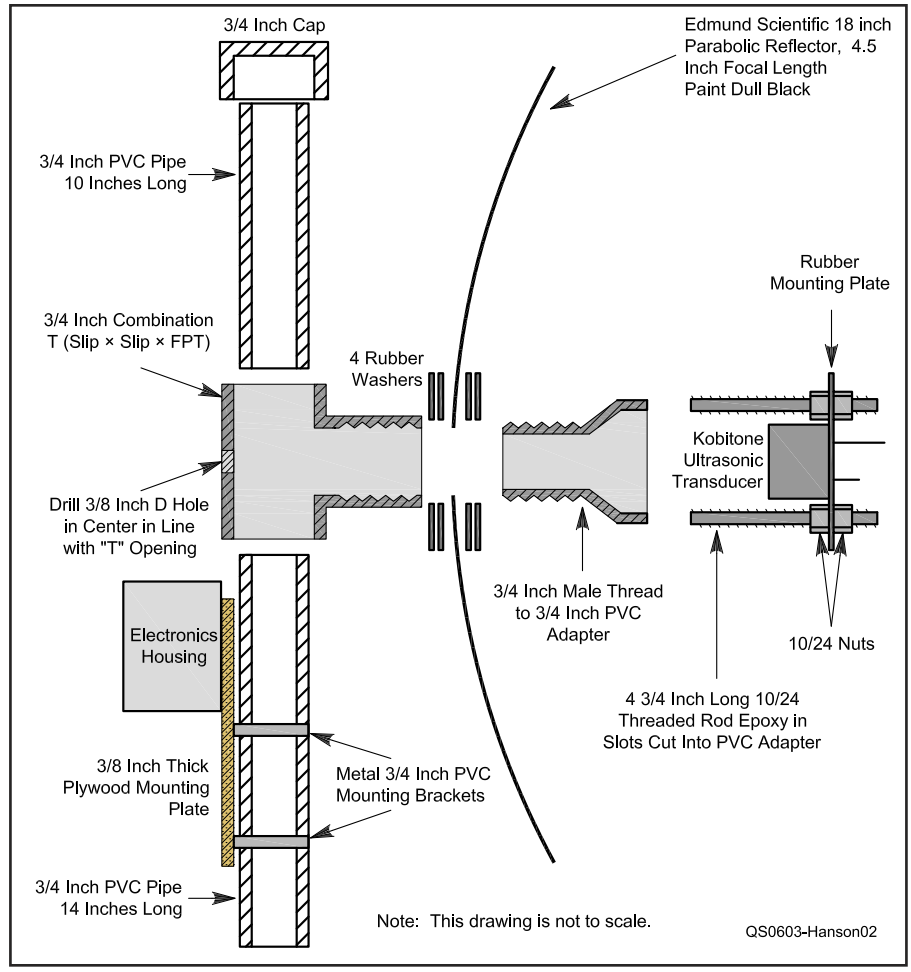

Figure 2 — Ultrasonic dish assembly.

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- In the original design, the microphone was held in place with elastic bands. The reason for this was to isolate the microphone from the mechanical assembly. I wanted something that would be more rugged, so the design modification for ultrasonic use uses a piece of the same ⅛ inch rubber gasket material used for the PVC gaskets to support the ultrasonic sensor.
- I added a ⅜ inch hole in the back of the PVC T connector. This provides a shorter path for the shielded wire from the sensor to the electronics and also provides a sight so that you can see in the direction that the sensor is pointed.
- I increased the length of the top PVC pipe to provide a better place to hold the complete assembly.

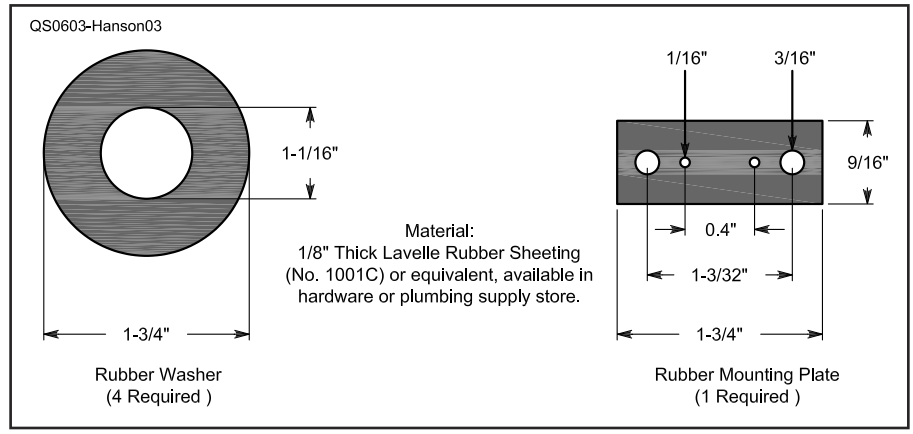

Figure 3 — Rubber washer and mounting plate details.

Putting it Together

All of the components of the mechanical assembly are shown in Figure 2. The Edmund Scientific parabolic dish is key to building a successful ultrasonic detector. This is an 18 inch aluminum dish with a 1.13 inch center hole and a 4.5 inch focal length. The center hole is a good fit for the PVC threaded pipe assemblies. Rubber gaskets cut from ⅛ inch gasket material provide a tight fit for the PVC threaded pipefitting. The drawing for the gaskets and the transducer holder are included in Figure 3. I purchased the gasket material at a local hardware store.

One thing that needs to be emphasized is the need to paint the parabolic dish. As the dish comes from Edmund Scientific, it is unpainted aluminum and it is quite an efficient reflector of light. One of the uses that Edmund Scientific advertises for the dish is a solar furnace. I tested this "feature" in February while the outside temperature was about 20°F. I poked a piece of wood through the dish hole and aimed the dish at the sun. In less than 30 seconds, the wood was smoking. It was scorched and would have burst into flame had I left it any longer. This convinced me to paint the dish, as I did not want to destroy the ultrasonic transducer if the dish were ever inadvertently aimed too close to the sun. I used a spray can of flat black paint to paint the dish. This greatly reduces the solar reflection but does not have any effect on the sound reflection characteristics of the dish.

The ultrasonic transducer wants to be positioned so that its smooth detector side (opposite from the leads) is at the focus of the dish and pointed at the dish. The 4.5 inch dish focal length turns out to be the actual depth of the dish. Because of this, the focal point can be found very easily by simply placing a straightedge across the dish edges and aligning the depth of the transducer so that it is aligned with the edge of the straightedge.

The electrical connection from the transducer is made with a length (about 12 inches) of small diameter (0.11 inch diameter) shielded wire. I had some wire in my junk box but you can also use RG-174 coax, which is about the same diameter. The shielded wire is soldered directly to the transducer and the soldered connections keep the transducer positioned and locked to the rubber plate. The only critical part of the connection is to connect the shield of the coax to the transducer terminal that is electrically connected to the case of the transducer. This can be checked with an ohmmeter. I found that this was the shorter of the two pins on my transducer. An RCA audio plug is used on the end that connects to the electronic converter box. The RCA plug will fit through the ⅜ inch hole that is drilled in the PVC T so the connection can be soldered before the wire is passed through the PVC pipe.

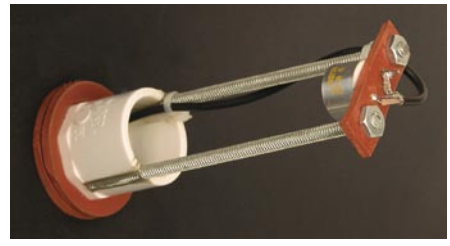

Figure 4 — Transducer mounting details.

The details of the final ultrasonic transducer assembly mounted to the parabolic dish are shown in Figure 4. The shielded cable is held to one of the 10-24 rods with small plastic tie wraps. The 10-24 nuts are used to adjust the position of the transducer so that it is properly positioned at the focus of the parabolic dish.

The schematic of the electronics is shown in Figure 5. The design is a modification of a downconverter that I found on one of the "Bat" Web sites.[4] The design shown in the schematic is based on one published in the December 1994 issue of *Popular Electronics*. I made several modifications to the original schematic, including the following:

- The original circuit used an LMC567 low power tone decoder for the oscillator. I replaced this with a TLC555 CMOS 555 timer chip operating in the multivibrator mode. The 555 is a very common chip and is readily available from multiple sources.
- I reduced the oscillator tuning range from the original 7.5 to 88 kHz to a range of 30 to 48 kHz. This covers the range required to detect 40 kHz arcing signals and makes setting of the oscillator much less critical.
- I changed both of the preamplifier transistors from 2N3904 to 2N4401, which have a lower audio noise figure, and have become a favorite with audio enthusiasts.
- I used a 6¼ × 3¾ × 2 inch plastic enclosure that I had to house the electronics. A cover plate was fabricated from a piece of scrap aluminum. RadioShack used to sell these housings with a cover plate, but it is no longer a RadioShack item. Keystone Electronics makes the same size box, and the box and an aluminum cover are available from Digi-Key. There is nothing critical about the box other than it needs to be able to hold the electronics and a 9 V battery.

The circuit was built on a RadioShack 2$^{13}/_{16}$ × 3¾ inch "universal component PC board" (part number 276-168). This board has 0.1 inch hole spacing, which will accept standard dip packages. It also has two separate buses, which are used for power and ground connections. Figure 6 is a photograph of the finished circuit. The layout is straightforward and follows the schematic.

The input preamplifier section is in the lower left-hand corner of the picture and connects to the RCA input jack. Just to the right and slightly above is the mixer, and the audio amplifier section is to the far right. The oscillator is at the top of the board. The circuit board and all of the connectors and controls are mounted to the housing aluminum cover plate. I made some small rubber washers out of the same ⅛ inch rubber gasket material and used two at each corner to space the circuit board off the cover plate.

I mounted the electronics enclosure to a

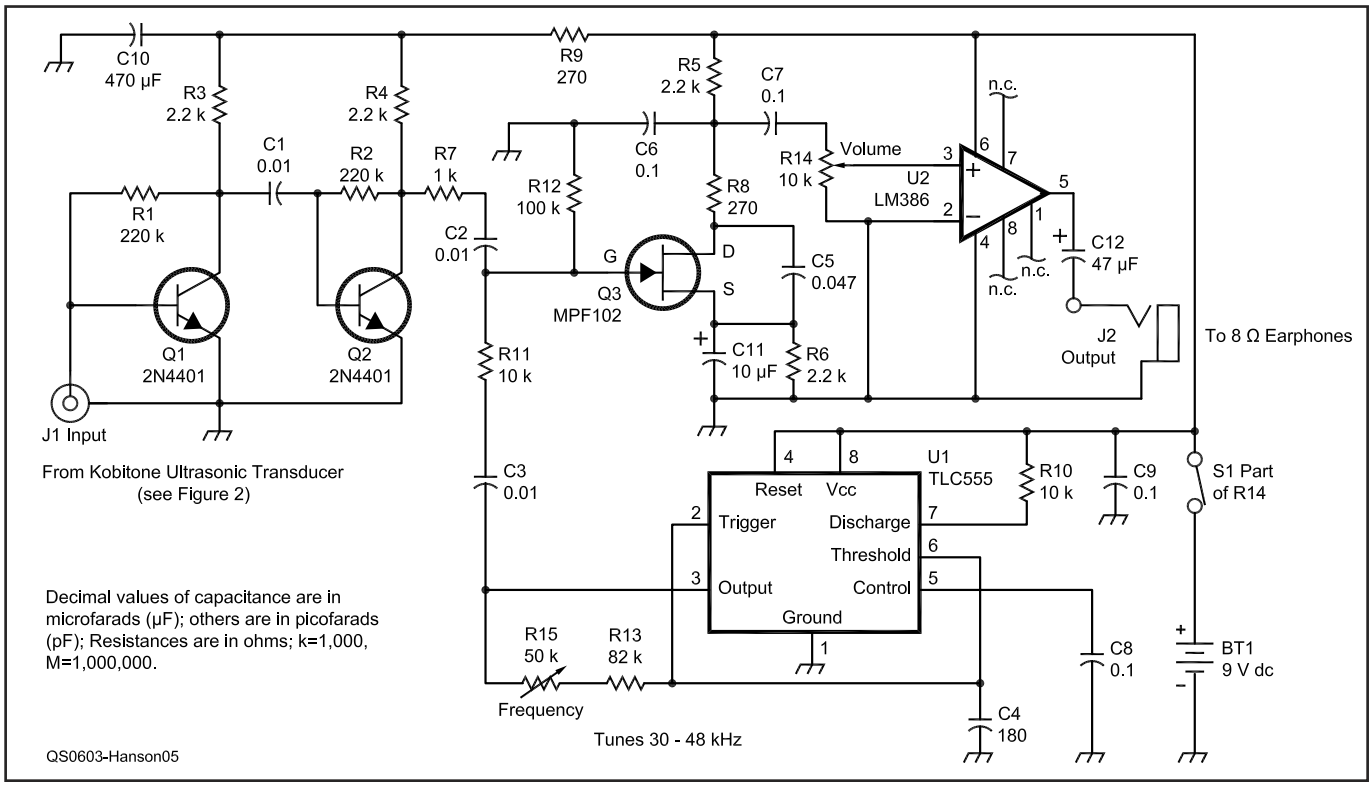

Figure 5 — Ultrasonic detector schematic and parts list. Most components are stocked by RadioShack, www.radioshack.com; Mouser, www.mouser.com, or Digi-Key, www.digikey.com.

BT1 — 9 V "transistor" battery.
C1-C3 — 0.01 µF, 100 V subminiature polyester capacitor (Mouser 140-PM2A103K).
C4 — 180 pF COG (NPO) multilayer ceramic (Mouser 80-C315C181J1G).
C5 — 0.047 µF, 100 V subminiature polyester capacitor (Mouser 140-PM2A473K).
C6-C9 — 0.1 µF, 100 V subminiature polyester capacitor (Mouser 140-PM2A104K).
C10 — 470 µF, 25 V capacitor (Mouser 140-XRL25V470).
C11 — 10 µF, 35 V capacitor (Mouser 140-XRL25V10).
C12 — 47 µF, 35 V capacitor (Mouser 140-XRL25V47).
J1 — Panel mount RCA jack (Mouser 161-1002).
J2 — ¼ inch panel mount phone jack (Mouser 161-1804).
P1 — Small RCA plug (Mouser 17PP050).
Q1, Q2 — 2N4401 (Mouser 610-4401).
Q3 — MPF102 (Mouser 512-MPF102).
R1, R2 — 220 kΩ, ¼ W (Mouser 660-CF1/4L 224J).
R3-R6 — 2.2 kΩ, ¼ W (Mouser 660-CF1/4L 222J).
R7 — 1 kΩ, ¼ W (Mouser 660-CF1/4L 102J).
R8, R9 — 270 Ω, ¼ W (Mouser 660-CF1/4L 271J).
R10, R11 — 10 kΩ, ¼ W (Mouser 660-CF1/4L 103J).
R12 — 100 kΩ, ¼ W (Mouser 660-CF1/4L 104J).
R13 — 82 kΩ, ¼ W (Mouser 660-CF1/4L 823J).
R14 — 10 kΩ, audio control with SPST switch (Mouser 31XP401).
R15 — 50 kΩ, linear taper potentiometer (Mouser 31VA405).
S1 — Part of R14.
U1 — TLC555 CMOS 555 timer (RadioShack 276-1718).
U2 — LM386 audio amplifier (RadioShack 276-1731).
Ultrasonic transducer, Kobitone 255-400ER18 (Mouser 255-400ER18).
Plastic enclosure — 6¼ × 3¾ × 2 inch, Keystone Electronics (Digi-Key 700K-ND).
Cover — Plastic Enclosure Aluminum Keystone Electronics (Digi-Key 2046K-ND).
Universal component PC Board 2 13/16 × 3¾ inch (RadioShack 276-168).
Parabolic reflector — 18 inch diameter (Edmund Scientific 3080254).

6¼ × 4 inch piece of ⅜ inch plywood and mounted the plywood to the PVC pipe with a pair of two hole galvanized tubing straps. The board was left over from a previous project. This arrangement allows the electronics box to be removed from the PVC pipe without opening the electronics box. The electronics box could be mounted directly to the PVC pipe without the plywood if desired. Figure 7 is a photo of the front panel. The rear view of the completed detector is shown in Figure 8.

Testing Out the Detector

Plug a pair of 8 Ω headphones into the ¼ inch jack and turn on the power. You should hear a white noise rushing sound, which will change slightly as you adjust the frequency control. The only adjustment that has to be made is setting the frequency of the 555 oscillator. Set the frequency to about 39 kHz, which will tune the downconverter for a 40 kHz input signal. There are several ways that the frequency can be set.

I had an ultrasonic transmit transducer, which I connected to a signal generator adjusted for 40 kHz at a very low output. It was then a simple matter to aim the dish at the transmit transducer and adjust the frequency control until I could hear the audio tone in the earphones. I marked this point on the front panel so that I could easily set the oscillator to the correct frequency.

You can also set the oscillator frequency with a frequency counter or an oscilloscope connected to the junction of R11 and C2.

The following procedure, which does not require any special test equipment, can also be used. You can generate an ultrasonic signal by gently rubbing your fingers together. If you do this in front of the dish, you should be able to hear the sound quite loudly. Turn down the volume until you can just hear the sound of your rubbing fingers and carefully adjust the frequency control for the loudest sound. You may want to reduce the volume further as you make the final frequency adjustment. Place a mark on the front panel where the frequency control is. That is all there is to it — you are now ready to go hunting for arcing insulators on power lines.

Using the Ultrasonic Detector

The Ultrasonic detector should not be

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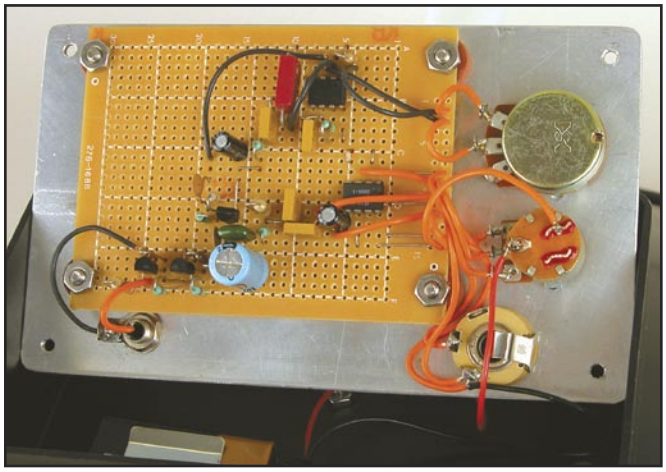


Figure 6 — Ultrasonic detector electronic assembly.

Figure 7 — Ultrasonic detector front panel.

used as the primary tool to hunt for power line noise. The techniques outlined in Notes 1 and 2 should be followed to find the general area of the noise. I have been able to get the heading of the noise by rotating my triband beam while monitoring the noise on 10, 15 or 20 meters with the receiver in the AM position. I have had some success finding the initial area by driving around with my car and listening to the AM radio tuned to the very high frequency end of the band. When I am in the vicinity of the noise, I have had very good luck using the MFJ-852 power line noise meter to narrow down the search. This VHF AM receiver has a signal strength meter with a 50 dB range and is very useful for tracking down the source. I have found that when I get close to the source of noise, the meter will be close to full scale.

Once you are in the vicinity of the problem pole, it is time to bring out the ultrasonic detector. To aim the parabolic dish, site through the ⅜ inch hole drilled into the PVC T and center the ultrasonic transducer in the hole. There is enough of a gap around the transducer to allow you to see the wires and insulators on the pole. If arcing is occurring, you should hear a deep growl when you are pointing at the arcing source. The exact sound can be different, depending on the exact nature of the arcing. Arcing can consist of single or multiple spikes at a 60 or 120 Hz rate, and each will make a unique sound.

If you read some of the reference material about ultrasonic detectors, they will mention that, if there is blockage between you and the arc, it will not be possible to hear the arc. My experience has been that, although the amplitude has varied, I have been able to hear the arc on all of the poles that I have investigated to date.

The ultrasonic detector is only one of several tools that can be used to track down radio noise. An ultrasonic detector can get you very close to determining the location of the problem on a pole. It is also a very good verification that a problem exists, but the final determination of what needs to be fixed and how to fix it should be left up to the utility company. Remember that they are the experts. The value of the ultrasonic detector is that it provides very good and convincing evidence that a problem exists on a given pole. It is very difficult for the utility company to ignore the fact that you are hearing actual arcing. It is also possible to record the detector output and to convert the sound to an audio file if further proof is required.

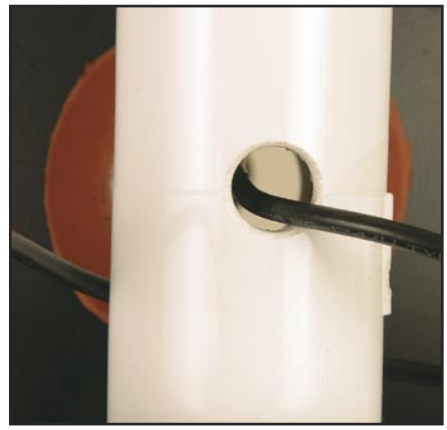


Figure 8 — Rear view of completed ultrasonic detector.

Good hunting!

Notes

[1]"Track and Solve Electrical Interference," **www.arrl.org/tis/info/rfi-elec.html**.

[2]M. Loftness, KB7KK, *AC Power Interference Handbook*. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9055, telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop/**; **pubsales@arrl.org**.

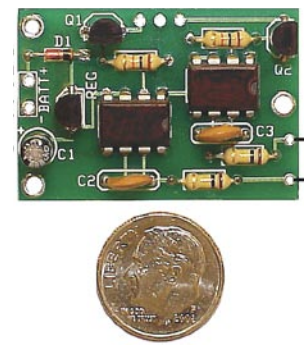
[3]G. Kunkel, "Parabolic Microphone Design," **web.archive.org/web/20041023131641/ourworld.compuserve.com/homepages/G_Kunkel/microphone.htm**.

[4]"Bat Detector," *Popular Electronics*, Dec 1994, **www.njsas.org/projects/bat_detector/heterodyne.html**.

Jim Hanson, W1TRC, has been an ARRL member for over 50 years. He received his General class license in 1951, his Advanced class license in 1952 and his Amateur Extra class license in 1984. His primary ham radio interest has been working DX and he is at the top of the phone and mixed DXCC honor roll. Jim has a BS degree in electrical engineering and has been retired from Raytheon Company Inc since 2004 where he worked on radar receiver and low noise exciter designs. He holds several patents relating to radar design. You can reach the author at 8 Ethelyn Circle, Maynard, MA 01754 or **w1trc@arrl.net**.

New Products

CWTOUCHKEYER P3 TOUCH PADDLE



◊The P3 touch paddle circuit board can be used to make your own touch-sensitive keyer paddle or straight key. Just add the conductive metal objects of your choice for the paddle contacts, and provide 5 to 14 V dc at 2 mA for power. The PC board measures 1.5×1 inches and paddle contacts can be mounted up to 24 inches away. Price: $28 assembled or $18 in kit form. To order or for more information, visit **www.touchpaddle.com** or contact Sumner Eagerman, WA1JOS, 14 Boutas Dr, Norton, MA 02766; tel 508-285-7600.

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